Multilayer coatings for the lithography generation beyond EUVL

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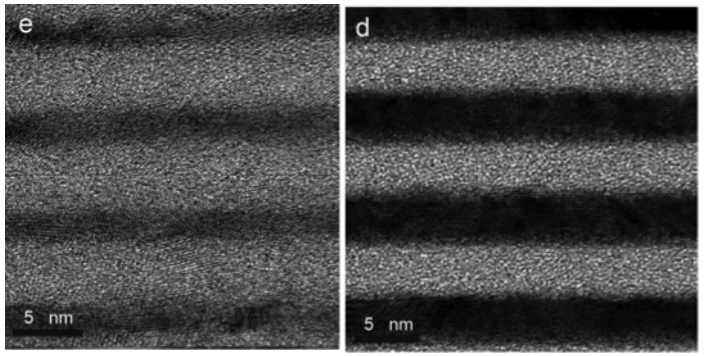
Outline

- Introduction
- Potential of La/B-based multilayer mirrors
- Source/optics matching: multilayer reflectivity at 6.775 nm
- Current status of multilayer reflectivity

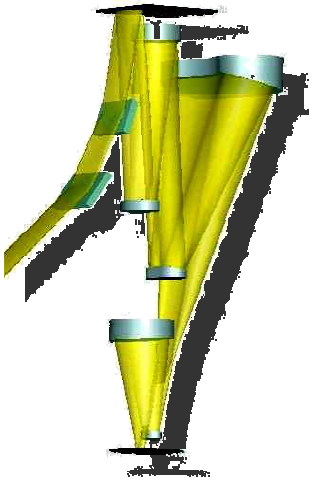
Scaling EUV to BEUV/6.X nm

Challenges for the multilayer systems



➢2x reduced bi-layer thickness: 6.8 → 3.4 nm
- Stricter interface control required

➢New materials: Mo > La, Si > B/B_4C
- Layer intermixing/chemical activity
- Interface roughness
- Optical contrast

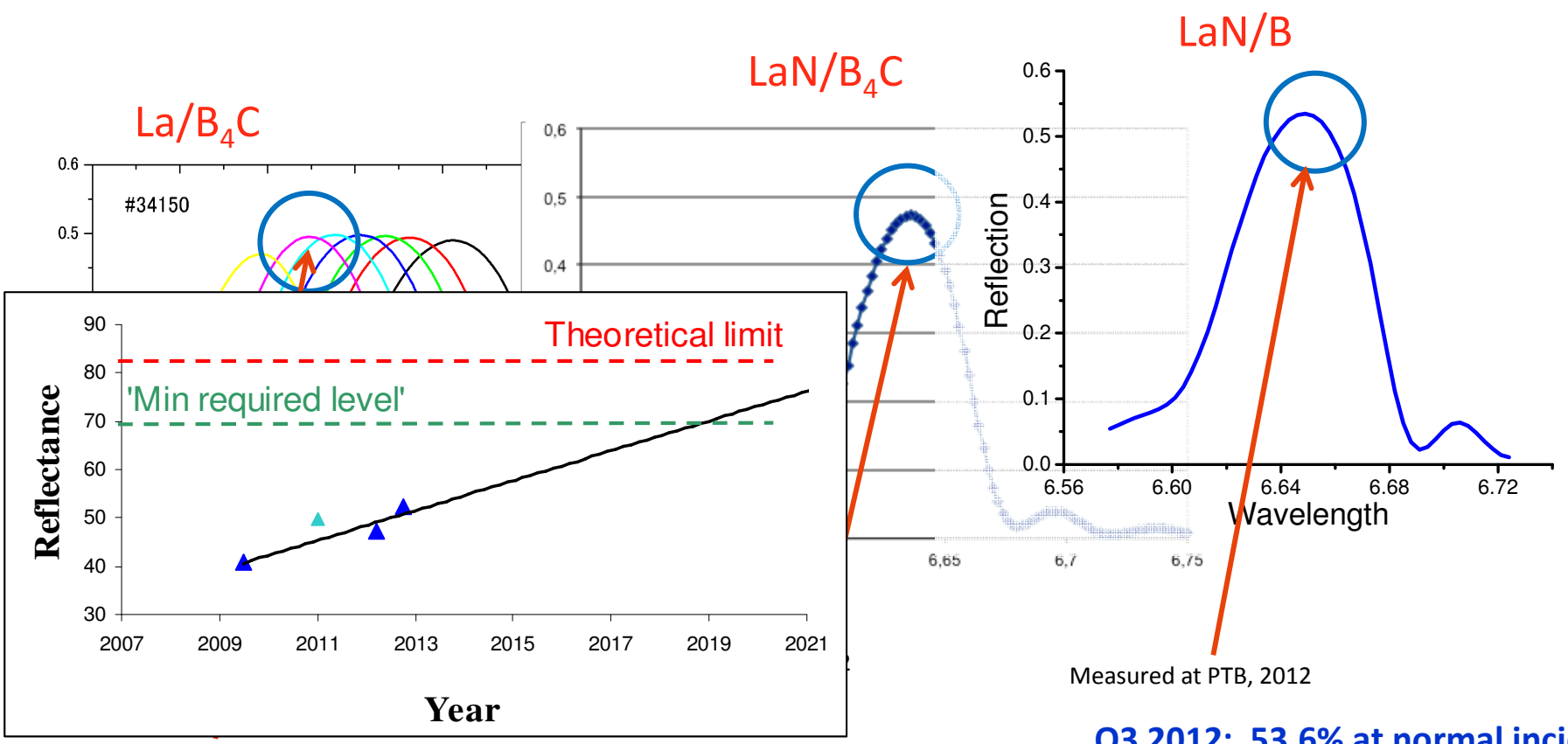


➢4 x more bi-layers: N~200 (comp to ~50 for Mo/Si)
- Bandwidth optical column 0.6% (comp 2% for Mo/Si)
- Higher deposition control required

Can it be done?

➔ Yes, when based on learning from 13 nm know how

Current status of multilayer development



49.83%

Rigaku Osmic EUV Optics

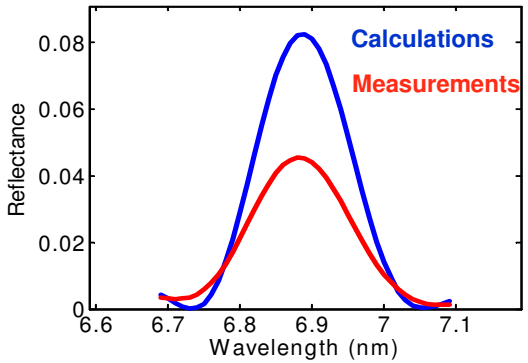
Courtesy Platonov, OSMIC

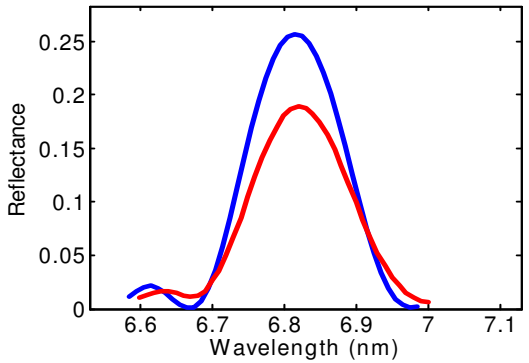
Q1 2012: 47.20%

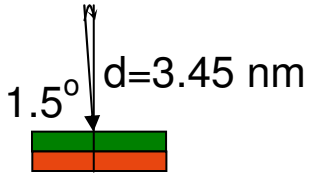
Q3 2012: 53.6% at normal incidence

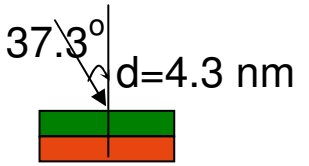
Analysis of reflectivity from "thick" MLs

40 period La/B multilayer mirrors with different period thicknesses:



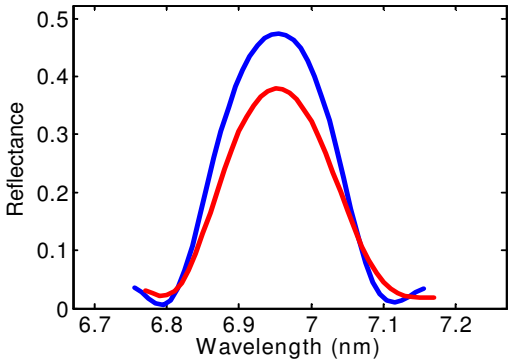


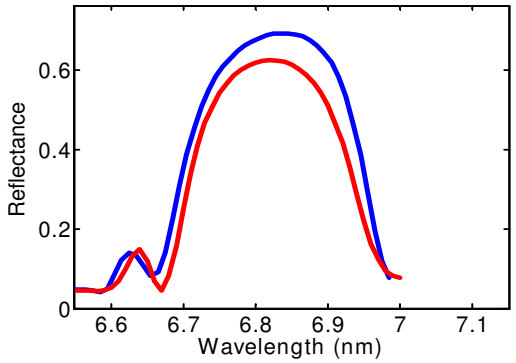


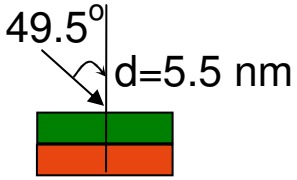


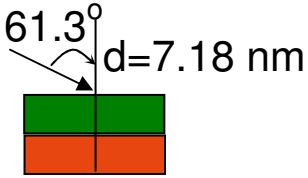
➢ Interface influence reduced→ reflectivity close to theoretical value

→ Total interface width ~1.5 nm
2 x reduction required to achieve 90% of theoretical nni reflectance



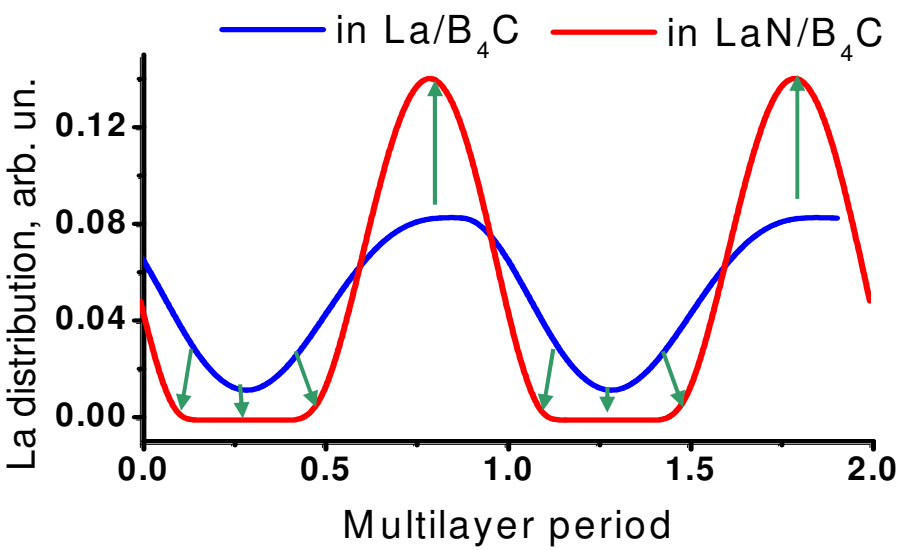




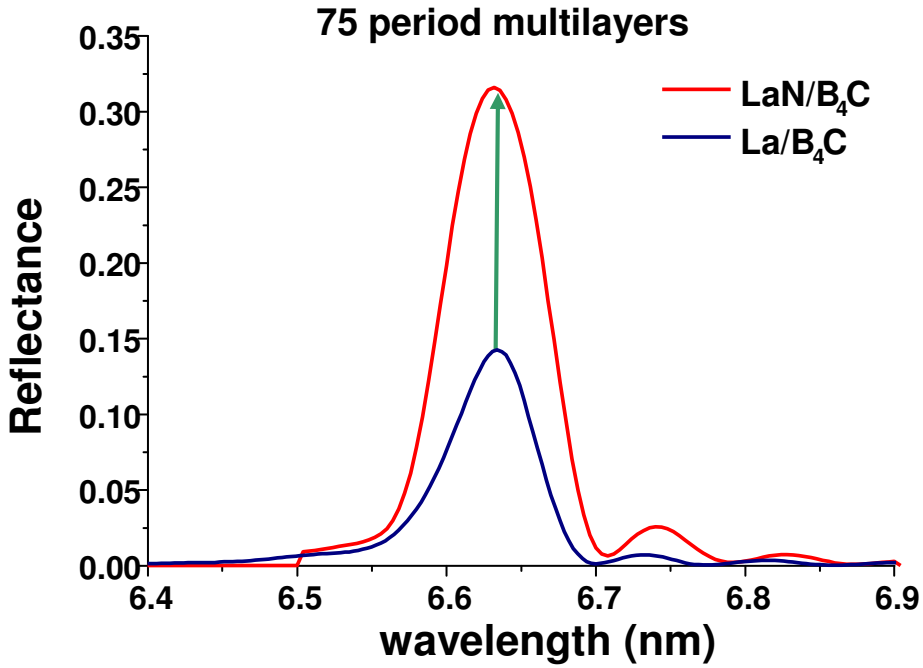


➢ Optical contrast to be improved

La → LaN: improvement of the interface conditions



Reconstruction of La depth profile



Compound	*La*	*B_4C*	*LaC_2*	*LaB_6*	*LaN*
ΔH^{for} (kJ/mol)	*0*	*-71*	*-89*	*-130*	*-303*

Dramatic difference in maximum reflectance

(75 period multilayers without any process optimization)

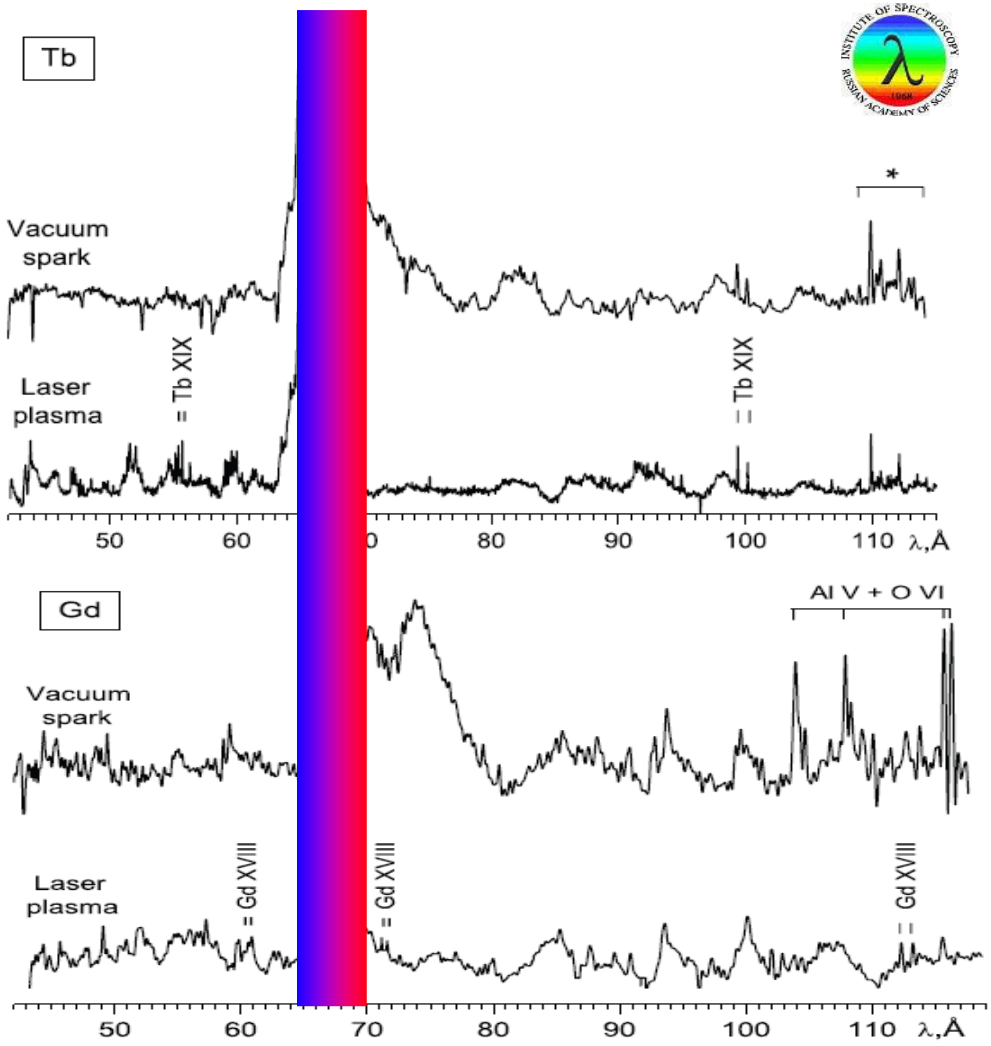
What about the source?

Selection of wavelength 6.x nm lithography:

Simultaneous optimization required:

- source
- multilayer performance
- optical design
- …

→ Wavelength: 6.5-7.0 nm



S.S. Churilov et al., Phys. Scr. 80 (2009)

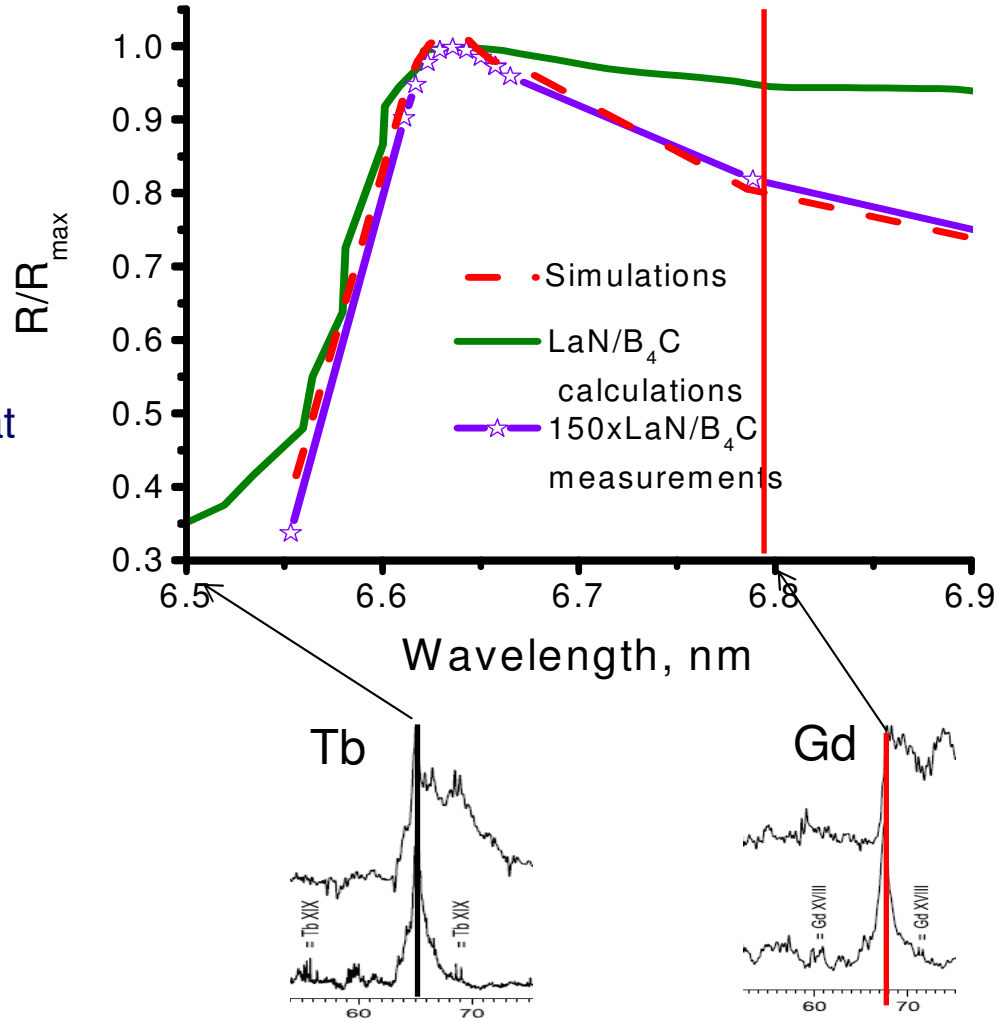
Calculated multilayer reflectance spectra

Optical constants:
- R. Soufli et. al., Appl. Opt., Vol. 47, 25, 2008
- M. Fernandez-Perea et. al., J. Opt. Soc. Am. A, Vol. 24, 12, 2007

6.64 nm: ☺ Optimal ML reflectivity
☹ Only Tb as a source
> 6.78 nm: ☹ ML performance drops
☺ Optimal wavelength for Gd

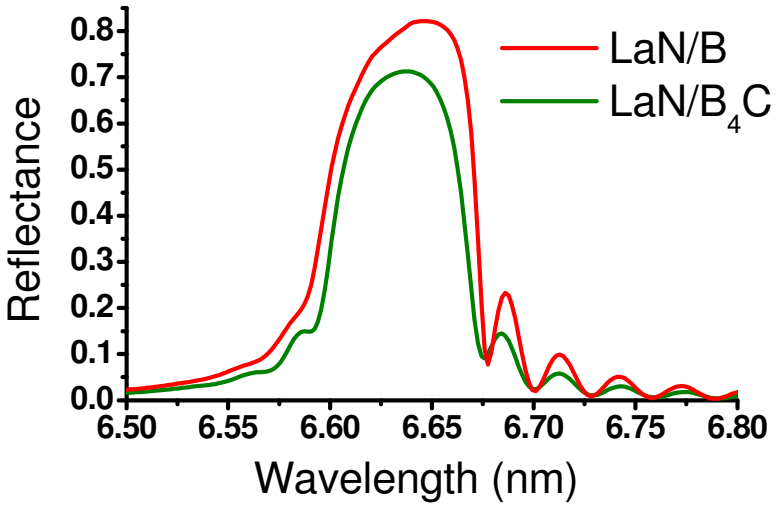
- Measured reflectance: stronger decay at longer wavelength
- Reduced optical contrast

- Optical contrast needs to be enhanced!

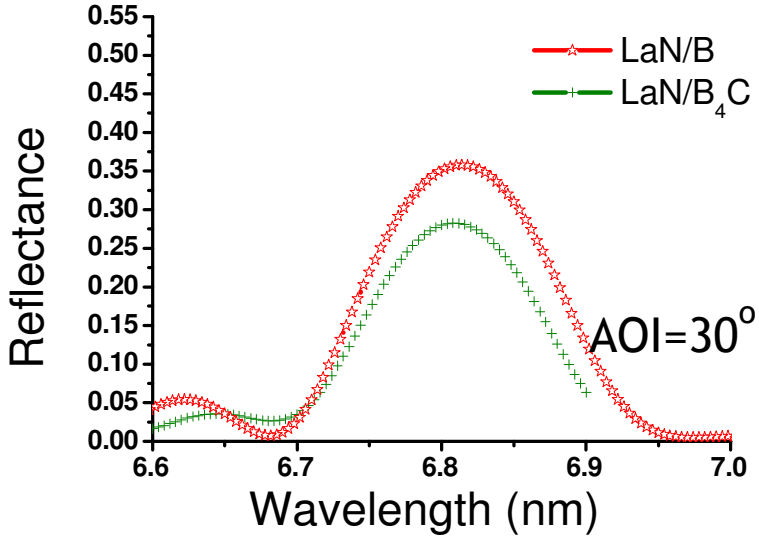


B_4C to B transition

200 period ML's



50 period ML's



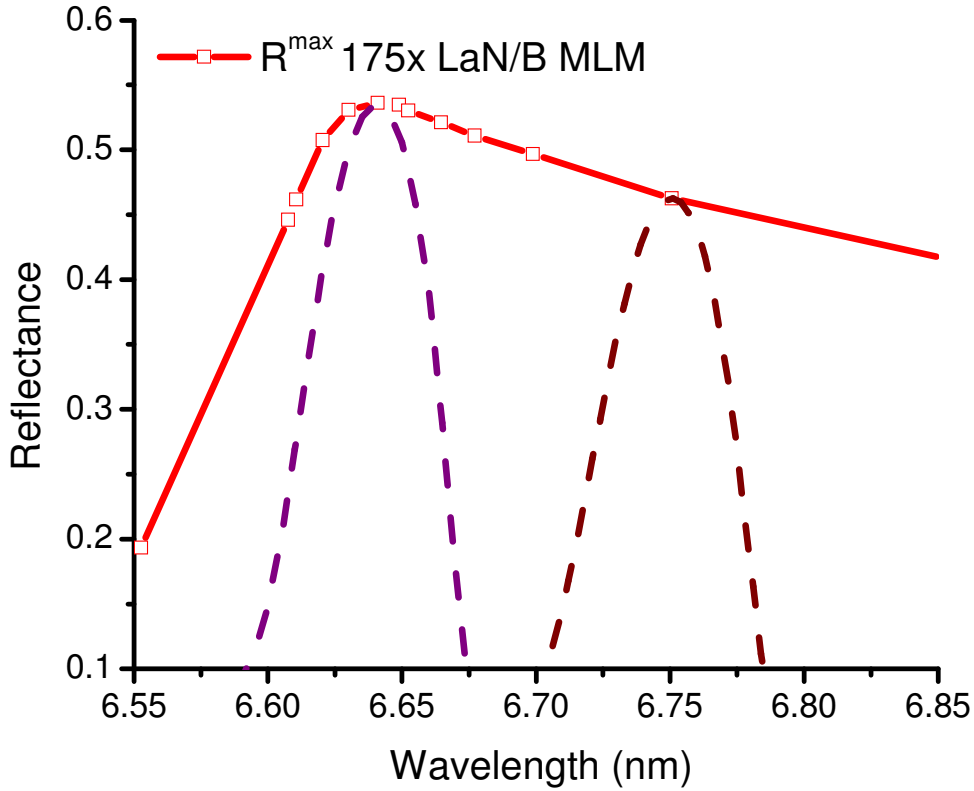
Calculations on ideal multilayers using measured optical constants:

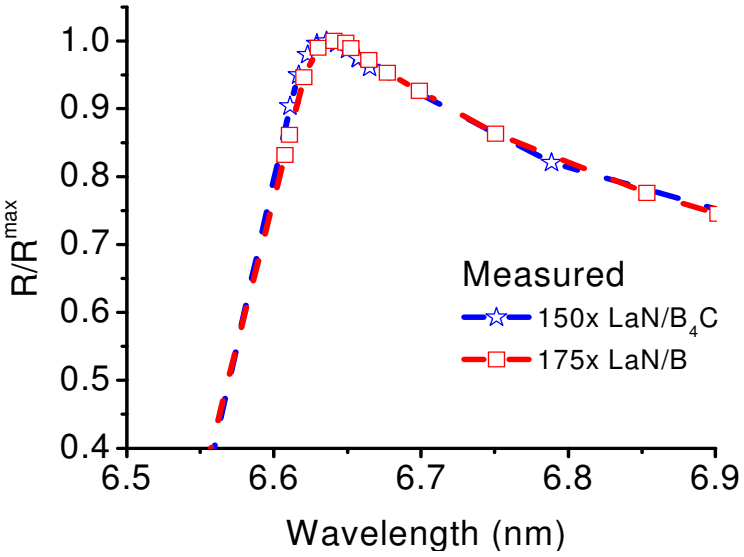
Less absorption → 10% reflectivity gain

Measurements of pilot samples confirm reflectivity gain

Replacement B_4C→B: enhancement of the optical contrast

175 period LaN/B: 53.6% normal incidence R





LaN/B:

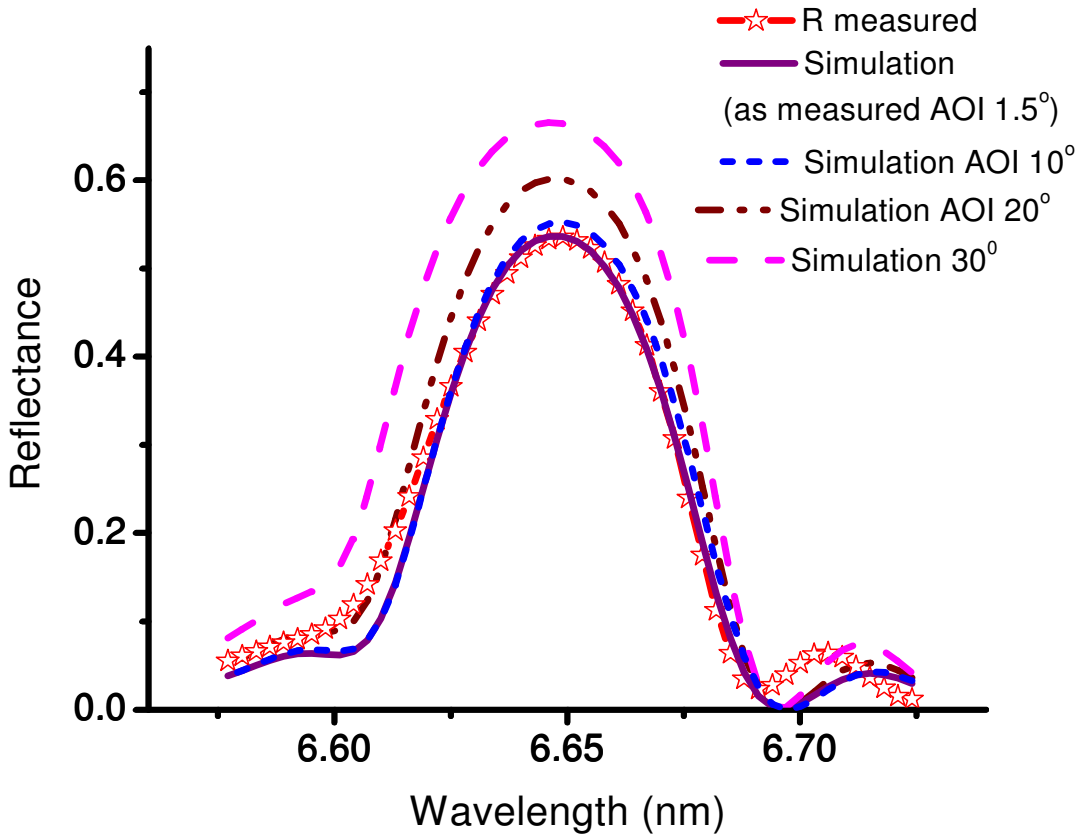
→Highest nni reflectivity at 6.64 nm: 53.6%

→Optimization optical contrast still required

Grazing AOI

- Fit measured reflectance→ structural modal
- Structural model → reflectivity simulation @ various AOI

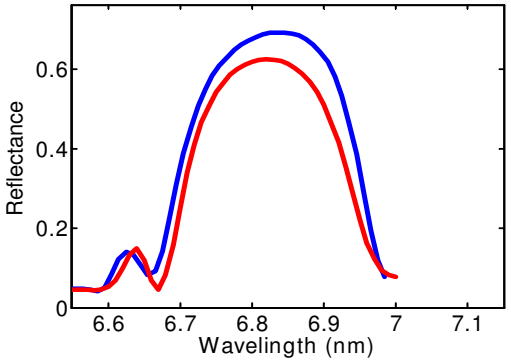
1.5^0 (measured) : 53.6%
10^0 : 55 ± 2%
20^0 : 60 ± 2%
30^0 : 66 ± 2%

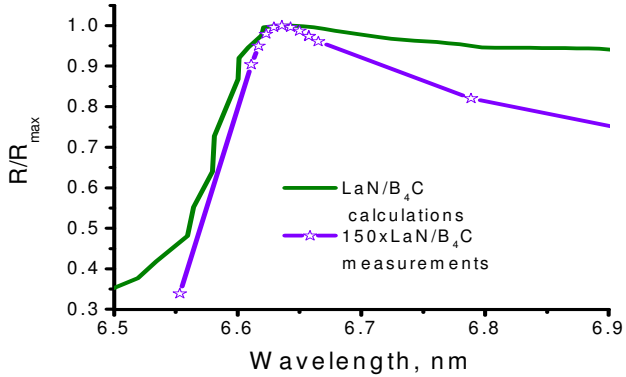


Summary

Potential of La/B-based multilayer mirrors:

→If interface imperfections influence is reduced: close to theoretical reflectivity is observed



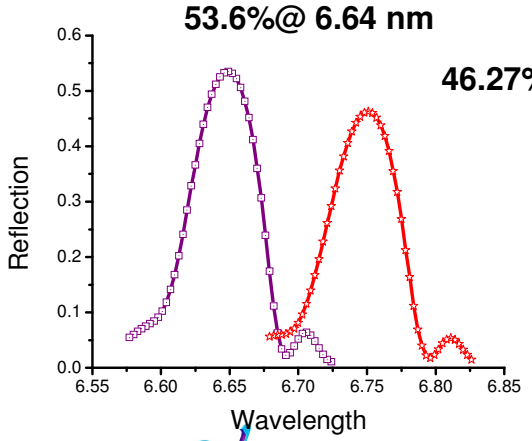


Source/optics matching: wavelength selection:

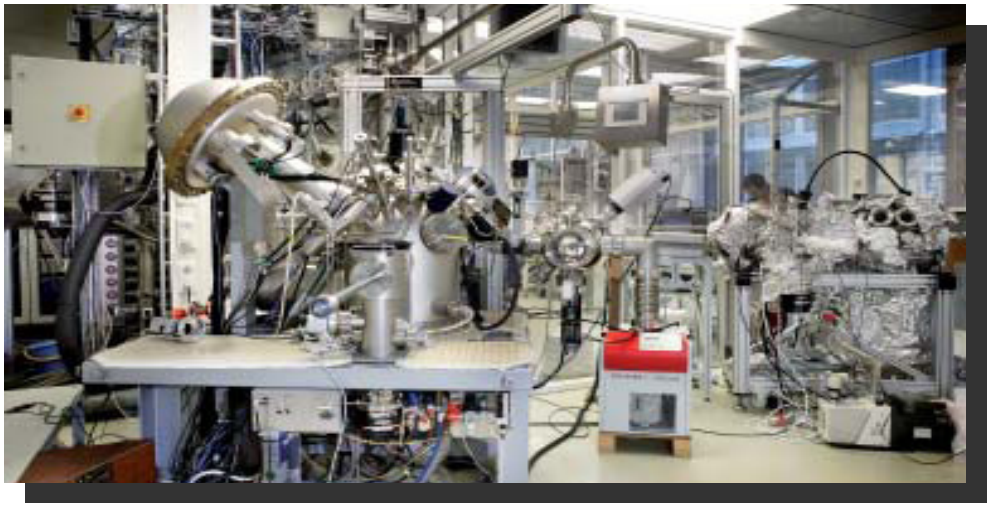
→ Transition from 6.6 to 6.8 nm: optical contrast determines reflectivity drop

Current status of multilayer reflectivity:

→Highest normal incidence reflectivity of 53.6% for LaN/B MLM, corresponding to ~60.0% at 20° AOI for s-polarized light.



New BEUV multilayer development program



XUV Optics Focus Group

- Focussed BEUV thin film & multilayer R & D programme
- Part of top Dutch Nanotechnology center MESA+, The Netherlands
- Funding from industry, regional and national governments

UNIVERSITEIT TWENTE.

provincie Overijssel

STW Nieuwe technologie mogelijk maken

ZEISS

ASML

MESA+ INSTITUTE FOR NANOTECHNOLOGY

Acknowledgements

FOM: Multilayer research & surface photochemistry

ASML EUV expts

MESA+: Optics & nanopatterning

Optics design, substrate & multilayer devlpt

PTB: EUV reflectometry